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Papageorgiou, Spyridon N

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TITLE PAGE

Discriminant analysis: what it is and what it is not

Spyridon N. Papageorgiou1

1 Clinic of Orthodontics and Pediatric Dentistry, Center of Dental Medicine, University of Zurich, Zurich, Switzerland

Corresponding author: Spyridon N Papageorgiou, Clinic of Orthodontics and Pediatric Dentistry, Center of Dental Medicine, University of Zurich, Plattenstrasse 11, Zurich CH 8032, Switzerland.
Email: snpapage@gmail.com.

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ORCID iD

Spyridon N Papageorgiou https://orcid.org/0000-0003-1968-3326

STATISTICAL CORNER

Theoretical scenario

A retrospective cohort study has been performed that aims to assess the stability of orthodontic treatment with fixed appliances following either a protocol involving extraction of four premolars or a protocol without any premolar extraction. In an effort to limit confounding factors the authors decide to use a discriminant analysis to identify a sample of borderline extraction/non-extraction patients, so that any differences in long-term treatment effects can be attributed to the different therapeutic protocols and not in any baseline differences.

The authors initially collected a parent sample of 500 Class II patients treated in a private practice and a university postgraduate orthodontic clinic, where treatment is done by orthodontic residents under the supervision of multiple clinical instructors. Cases with orofacial deformities, clefts, any history of previous orthodontic / orthognathic treatment, or extraction decision based on decay / periodontal reasons were excluded. All included patients had complete records including meticulous treatment charts, intraoral / extraoral photographs, dental casts, orthopantomograms, and lateral cephalometric radiographs (standardised in terms of settings and enlargement factor). Patients were treated with similar straightwire appliances without any extraoral appliances, adjuncts, or skeletal anchorage reinforcement devices.

This parent sample was subjected to a discriminant analysis (Paquette et al., 1992), in order to identify a borderline sample with regards to the extraction treatment. The discriminant analysis used 31 linear or angular cephalometric variables, 8 dental cast variables, and 2 patient demographics (age and sex) to incorporate most characteristics that might have been considered in forming treatment decisions. This analysis used statistical significance rules of statistical significance to add, eliminate, or retain in a stepwise statistical model all variables that statistically affect the treatment choice of extracting premolars or not. In the end, extraction treatment could be modelled statistically by a linear combination of just 6 variables: (i) lower arch length discrepancy, (ii) lower incisor protrusion (relative to NB), (iii) lower irregularity, (iv) upper arch-length discrepancy, (v) upper incisor protrusion (relative to SN), and (vi) profile convexity (Z angle formed by upper lip). The resulting standardized discriminant function with these 6 variables were then used to assign each patient of the parent sample ‘discriminant scores’ and patients whose discriminant score fell closest to the cut-off value for discrimination theoretically might have been treated either way and thus constituted the borderline sample of extraction and non-extraction patients. In this study, selected were patients within the borderline spectrum, such that their discriminant score was within one standard deviation from the cut-off point. Each extraction case was individually matched with a non-extraction case of the same gender and of approximately the same age, so that these parameters were equally distributed between the two groups.

The resulting borderline sample included 40 extraction and 40 non-extraction cases, whose dental cast models were measured at debond and 5 years after debond with the Peer Assessment Rating (PAR) index (Richmond et al., 1992) to assess the results’ stability and relapse. The authors found that the PAR scores 5 years after debond showed a similar deterioration for extraction and non-extraction patients without

any statistically significant differences (P>0.05). The authors concluded that as a discriminant analysis was utilised the borderline extraction / non-extraction patients were morphologically similar pre-treatment and the study provided robust evidence on similar relapse tendencies for extraction / non-extraction patients.

Which of the following statements are correct, if any:
(A) The robustness and applicability of any discriminant analysis is directly linked to the outcome or event that the discriminant analysis tries is modelled upon.
(B) As a discriminant analysis was used, the compared extraction and non-extraction groups were similar for all morphological characteristics.
(C) As a discriminant analysis was used, the expected risk and magnitude of relapse after debonding were similar for the compared extraction and non-extraction groups.

Discussion

To see if the above statements are correct or not, it is crucial to understand how the discriminant analysis works and how was it employed in this study. Discriminant analysis is in principle a multivariable regression analysis that tries to identify the combination of explanatory variables (independent variables) that best explain an outcome or event (dependent variable) in a parent sample. Afterwards, this combination of explanatory variables is used to assign each patient a 'discrimination score' and subsequently identify two subsets of the parent sample that are equally likely to present this event, as patients with extreme low / high scores (i.e. patients with extreme discrimination according to the selected variables) are excluded.

In the case of the present study, the discriminant analysis was employed to explain which patients received extraction treatment and which patients received non-extraction treatment. Strictly seen, the discriminant analysis tries to explain, which cases the specific treatment providers in the selected private practice and university clinic decided that could be better treated with or without extractions. Therefore, having a specific treatment plan decision as the dependent variable of the discriminant analysis introduces a certain subjectivity to the study. Treatment decisions to extract premolars or not premolars might be influenced by the specific school of thought, techniques used, proficiency, and even practice management decisions of each person. Inclusion of multiple persons with different scientific or clinical backgrounds might aid in alleviating some of the subjectivity and potential for proficiency bias, but is no panacea, and results of such studies and their applicability to other clinical settings should be carefully appraised. On the other hand, discriminant analyses that are used on clear-cut objective outcomes like miniscrew implant failure, development of gingival recession, or treatment success do not suffer from these issues. Statement (A) is obviously correct.

So in essence, the performed discriminant analysis did not formally assess the dental / skeletal / soft-tissue morphology of patients in the parent sample. Included in the final discriminant function could have been only those variables that (i) had been measured initially for treatment planning, (ii) were inputted in the statistical model, and (iii) were directly associated with the doctors' decision to extract or not. There have even been reported pre-treatment differences of 1° / 1mm in ANB / Wits appraisal (Paquette et al.,

1992), or 2° in SNA / SNB (Kouli et al., 2019), between such ‘borderline’ extraction / non-extraction groups, which might indicate baseline dissimilarity. So, morphological differences may well exist between groups after a discriminant analysis, if these differences would not lead the specific orthodontists of this study to a radically different treatment plan. Similarly, if a certain variable has not been included in the pre-treatment diagnostics or has not been retained in the final model due to poor performance of the statistical techniques used, pre-treatment equivalence cannot be guaranteed. Existing statistical issues of the analytic strategy like the stepwise model selection, choice of one SD from the cut-off score, and entry/removal rules based on statistical significance are not discussed here. But in any case, statement (B) is false.

Following the previous points, the assumption that the extraction / non-extraction groups that resulted from the discriminant analyses are similarly prone to dental relapse cannot be fully justified. First, the possibility of pre-treatment differences between groups cannot be excluded and such pre-treatment differences might potentially influence the expected relapse. Greater sagittal discrepancies might necessitate greater tooth movement, which might lead to greater instability. Likewise, different vertical skeletal patterns might be associated with different changes in the lower incisor region. Additionally, the current study has taken into consideration only the pre-treatment status of the patients. There is no information about any treatment-related changes and the occlusal outcome or finishing quality of the two groups after treatment, which is a potential risk factor for relapse. So statement (C) is false.

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